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Fabrication of Titanium Multiwall Thermal Protection System (TPS) Curved Panel

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FOREWORD

This is an interim report on work being performed by Rohr Industries - Design and Fabrication of Titanium Multiwall Thermal Protection System (TPS) - describing the Task IV activities. In Task IV, a titanium multiwall curved panel was fabricated and delivered to NASA Langley Research Center.

This program is administrated by the National Aeronautics and Space Administration Langley Research Center (NASA LaRC). Mr. John Shideler of the Aerothermal Loads Branch, Loads and Aeroelasticity Division, is technical monitor.

The following Rohr personnel were the principal contributors to the program during this reporting period: Winn Blair, Program Manager; Dale Jennings, Manufacturing Technology; R. H. Timms, Preliminary Design; and L. A. Wiech, Engineering Laboratory. Overall program responsibility is assigned to the Rohr Aerospace R&D Engineering organization with U. Bockenhauer, Manager.

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INTRODUCTION

Rohr Industries was awarded a contract January 1979 to design and fabricate titanium multiwall thermal protection panels for testing by NASA.

The initial program consisted of the preliminary design of flat panels and tooling, fabrication of flat test panels, and testing in face tension, flexural strength, creep, thermal conductivity, and emittance. Results of these tests were used to design and fabricate a nine-panel array for testing in the Langley Research Center 8-Foot-High Temperature Structures Tunnel. A two-panel array was fabricated and delivered to Langley Research Center for vibrational and acoustical tests. A second two-panel array was delivered to Johnson Space Center for radiant heating tests. This design and fabrication effort is documented in References 1 and 2.

An additional part of this program was to demonstrate that the multiwall concept could be fabricated as a curved panel. A curved titanium multiwall panel having a single radius of curvature of 305 mm (12 inches) was fabricated and delivered to NASA Langley Research Center. The panel's overall dimensions were 305 x 305 x 17.2 mm (12 x 12 x 0.680 inches). This report describes the design and fabrication of that panel.

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DESIGN

PANEL DESIGN

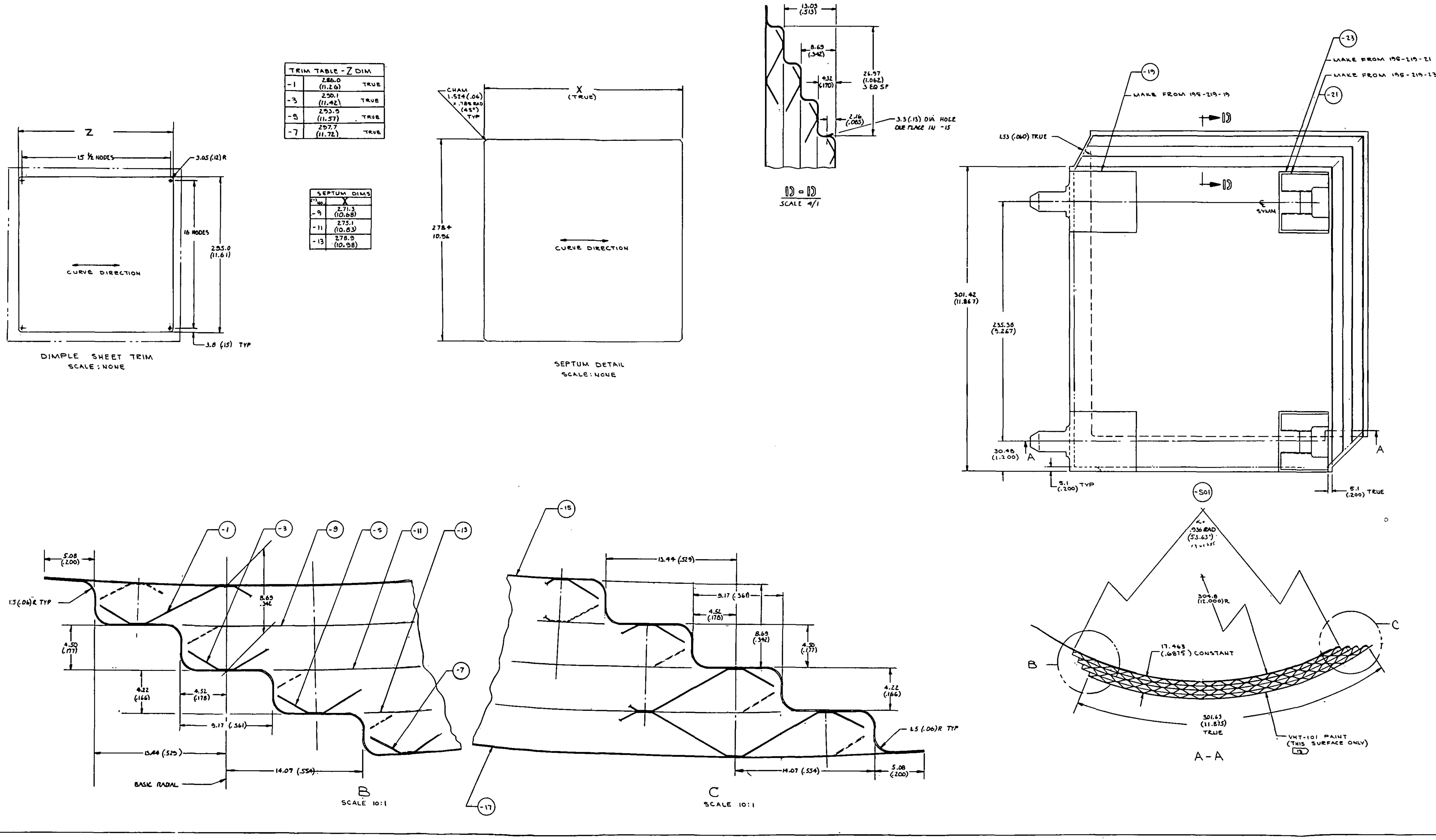
The panel assembly shown in Figure 1 was designed based upon experience gained during the fabrication and testing of flat panels (reported in References 1 and 2). Data obtained from testing of the flat panels, indicated that an enlarged node flat was necessary to improve flatwise face tension strength, and the 30-degree sloped side closure should be re-designed so that greater Liquid Interface Diffusion (LID) bonding pressure could be applied in that area of the panel. The design considerations for the curved panel are: 1) the ability to superplastically form Ti-6Al-4V into intricate shapes without severe degradation, 2) skins that are superplastically formed having a 30 degrees stepped angle on two sides that also close out the panel sides when LID bonded to the opposing skin, 3) panel sides that have four equally spaced steps that permit filler blocks to be used as aids for maximum pressure during the LID bond cycle, 4) dimpled sheets that have node flat diameter increased from 1.5 mm (0.060 inch) to 1.9 mm (0.075 inch) diameter, and 5) also have a different node pitch in the radial direction to achieve node alignment for the curved panel.

SKIN FORMING TOOL DESIGN

The tool design shown in Figure 2 takes into account the dimple spacing, and joining of the dimples to the steps of the side closures for maximum strength. The design also allows for both skins to be formed in the same basic tool by changing the side and end plates. Argon is used as the pressure media for superplastically forming the skins.

DIMPLED SHEET FORMING TOOL DESIGN

The design for the dimpled sheet forming tool shown in Figure 3 allows for the dimpled sheets to be formed flat then wrapped into the radial shape during layup for LID bonding. The pitch was varied on each of the 4 forming plates which allows the dimples to align with each other when wrapped to a 305 mm (12 inch) inside radius.



A COMPLETELY REVISED

NOTES

1. DIMS IN S.I. UNITS & (CUSTOMARY UNITS) mm (IN), RAD (DEG), N/m² (TORR), K° (°F)
2. TOLERANCES
   LINEAR X. = ±2 .X = ±.7 .XX = ±.25 (.X = ±.1)(.XX = ±.03)(.XXX = ±.010)
   ANGULAR .X = ±.1 .XX = ±.01 .XXX = ±.001 (X = ±2) (.X = ±.5) (.XX = ±.05)
3. MADE ON TOOL 195-234-501
4. " " " 195-234-503
5. " " " 195-234-505
6. " " " 195-234-507
7. " " " 195-236-501
8. " " " 195-236-503
9. PREPARATION FOR LID-BONDING:
   PLATE -1 ↔ -7 ON DIMPLE NODES ONLY
   PLATE -15 ↔ -23 ON INTERFACE SURFACES ONLY
10. STACK LAYERS OF -501 (VIEW B&C) & SPOT WELD PANS TO HOLD IN POSITION (SEE NOTE 11)
11. PARTS -15, -19, -21, -23 MAY BE BONDED PRIOR TO ASSY
12. BOND IN VACUUM FURNACE @ PRESSURE OF .0066 N/m² (5 × 10⁻⁵ TORR) & TEMP. 1214°K (1725°F)
13. PAINT TOP SURFACE WHITE VHT-101 .05 (.002) THICK
14. PERMISSIBLE WAVINESS ± .813 (.032)

Note	QTY REQD	PART NO.	DESCRIPTION	MATL.	SIZE	SPEC	H.T.
		AR	VHT-101 WHITE PAINT				
	2	-23	PAD	MAKE FROM 195-219-21			
	2	-21	TILE CLIP	MAKE FROM 195-219-23			
	2	-19	TONGUE	MAKE FROM 195-219-19			
8	1	-17	OUTER PAN	Ti 6Al-4V	.004 x 13 x 16		
7	1	-15	INNER PAN	Ti 6Al-4V	.003 x 13 x 16		
	1	-13	SEPTUM	Ti 6Al-4V	.0015 x 12 SQ		
	1	-11	SEPTUM				
	1	-9	SEPTUM				
5	1	-7	DIMPLE SH		.003 x 12 SQ		
4	1	-5					
3	1	-3					
6	1	-1	DIMPLE SH	Ti 6Al-4V			
	–	-501	PANEL ASSY				
	-501						

Figure 1. Panel Assembly

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Figure 2. Skin Forming Tool

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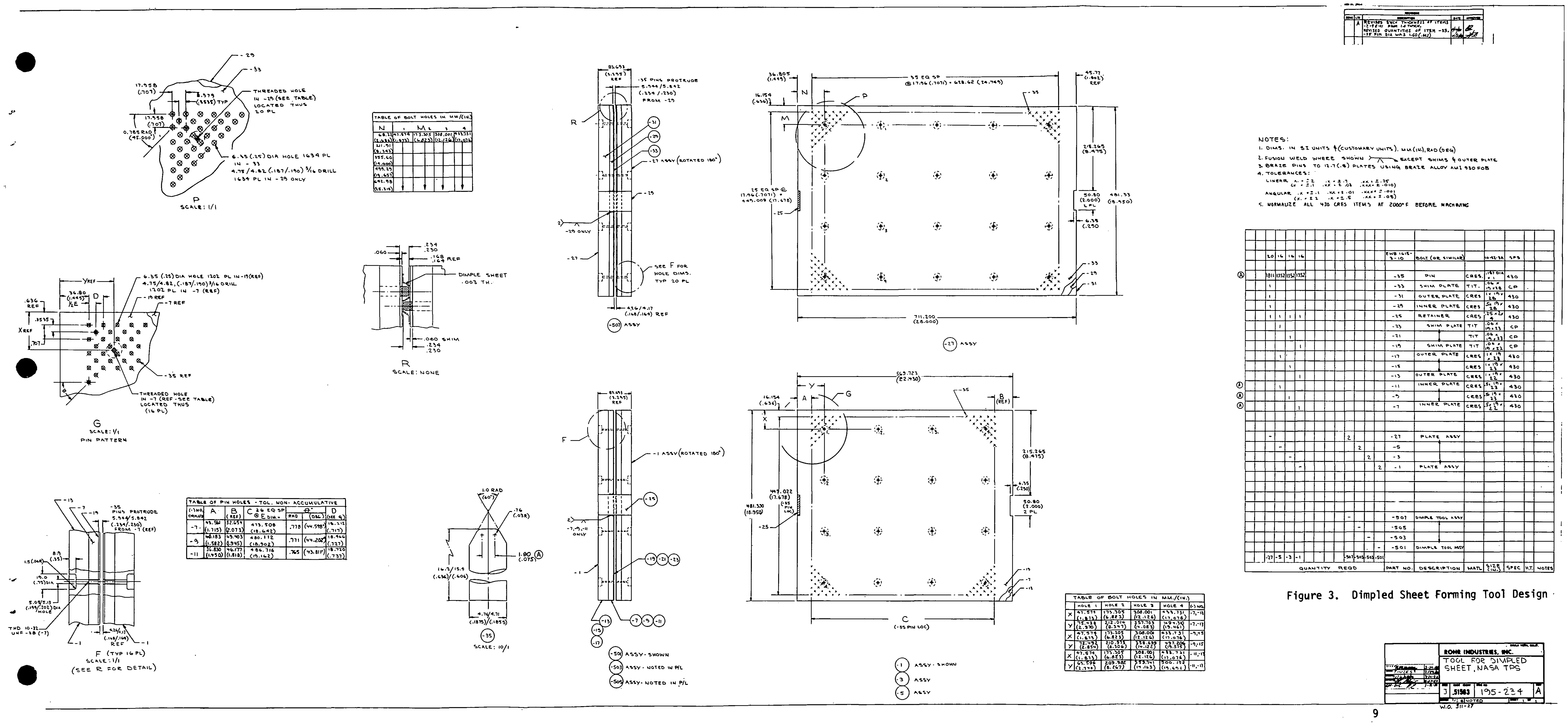

Figure 3. Dimpled Sheet Forming Tool Design

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PANEL FABRICATION

DIMPLED SHEET FORMING

The dimpled sheets, shown in Figure 4, were superplastically formed from 0.076 mm (0.003 inch) sheet in a vacuum furnace using 8.27 KPa (1.2 psi dead weight). Figure 5 shows the dimpled sheet forming tool ready to be loaded into the vacuum furnace. After forming, the dimpled sheets were trimmed using hand shears. Then the dimpled sheets were plated on the nodes only for LID bonding using the Rohr proprietary process.

SUPERPLASTIC FORMING THE SKINS

A flat sheet of Ti-6Al-4V.10 x 432 x 432 mm (0.004 inch x 17 inches x 17 inches) was placed in the superplastic forming tool shown in Figure 6. Then the tool was bolted together (shown in Figure 7) for forming. The tool was placed into a vacuum furnace and the furnace was evacuated to 1×10^{-5} torr, then heated to 1214 K (1725°F). At that temperature argon gas was introduced to the tool at 82.7 KPa (12 pounds per square inch) pressure for 15 minutes. The tool and part were furnace cooled to 425 K (300°F) before being removed from the furnace. The formed skin, shown in Figure 6, was trimmed to final size with hand shears. The skin was plated 5.08 mm (0.20 inch) wide around the periphery on the inside surface using the Rohr proprietary process.

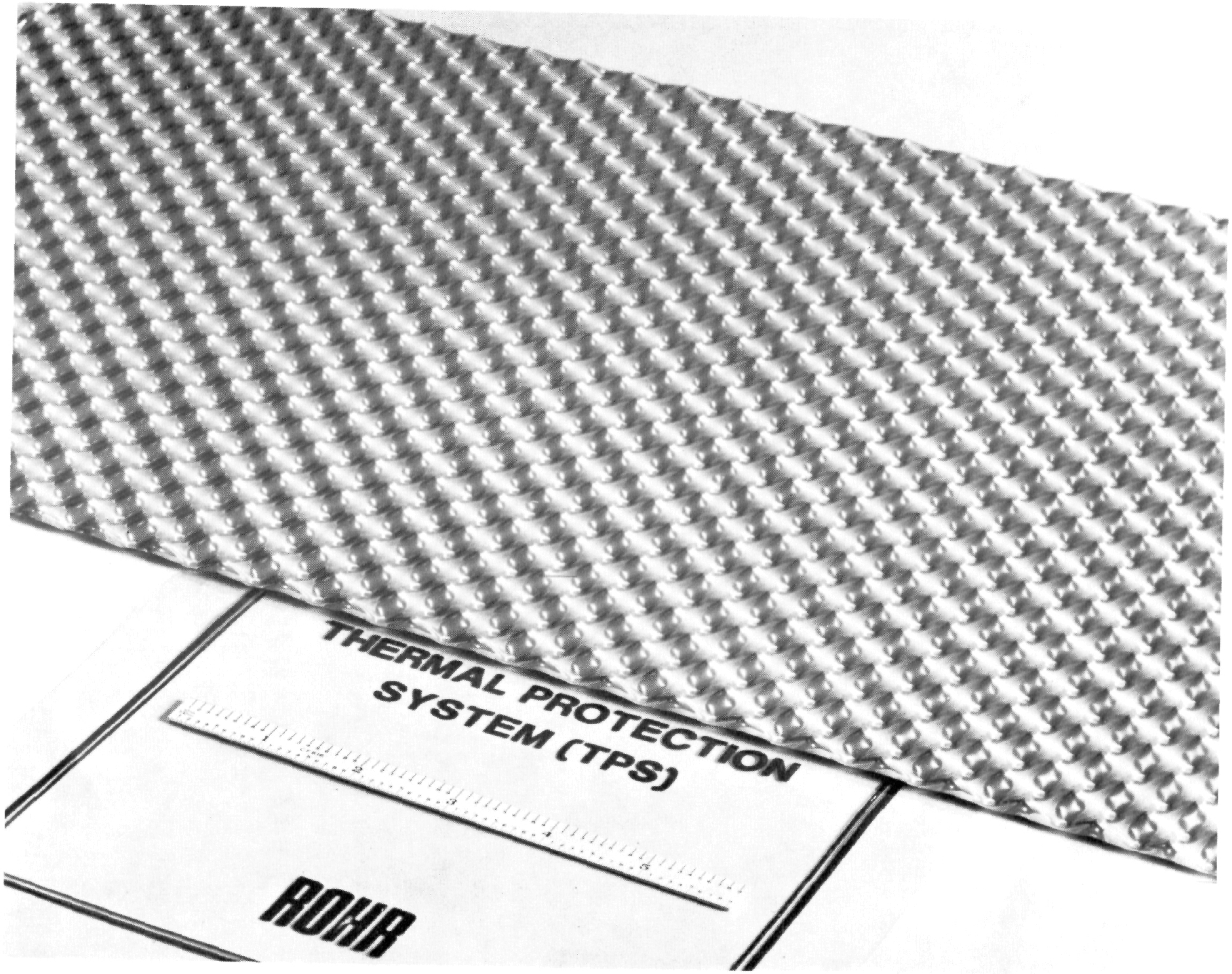

Figure 4. Superplastically Formed Dimpled Sheet

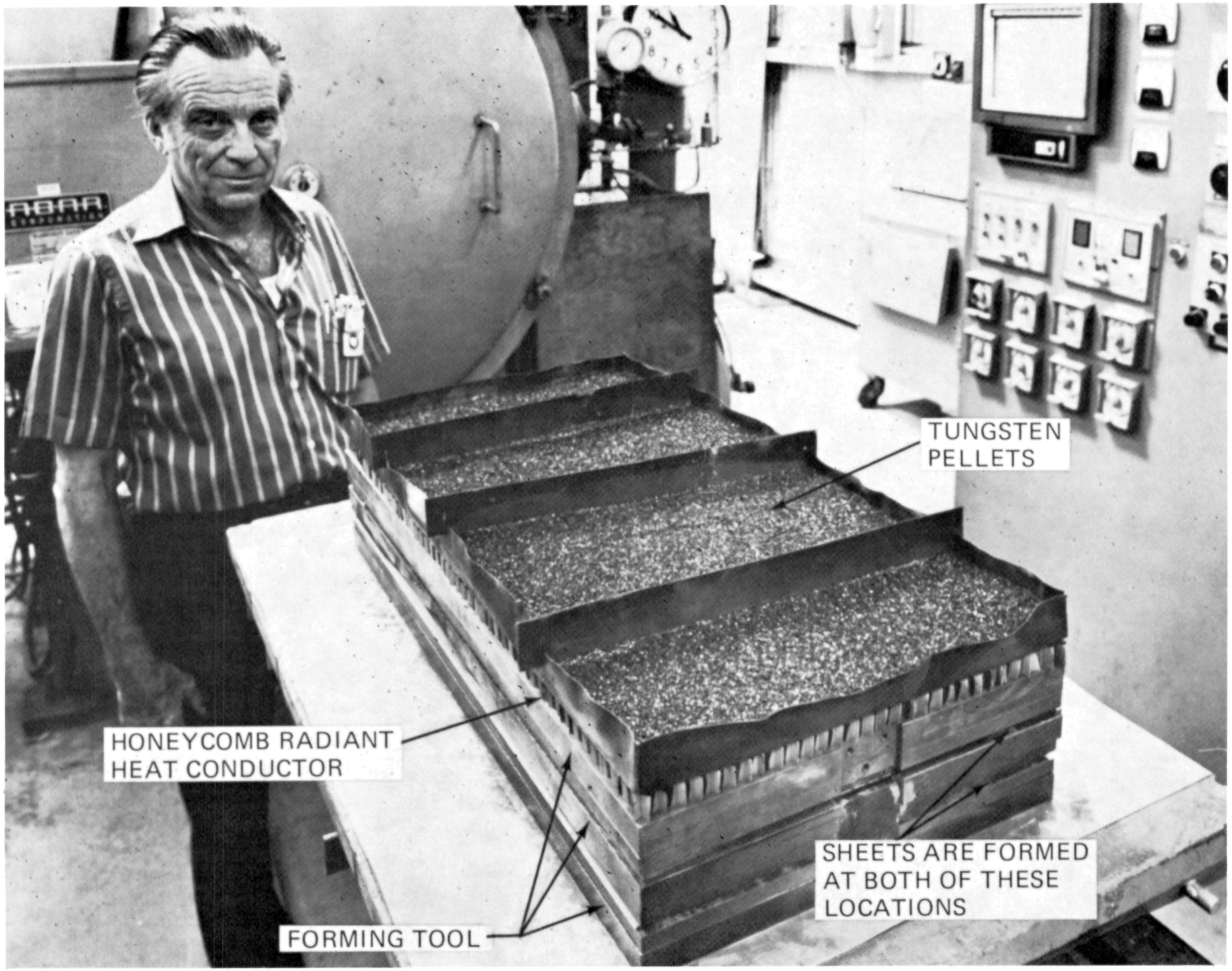

Figure 5. Superplastic Form Tool Ready for Loading into Vacuum Furnace

Figure 6. Tool for Superplastically Forming Skins and a Formed Skin (Untrimmed)

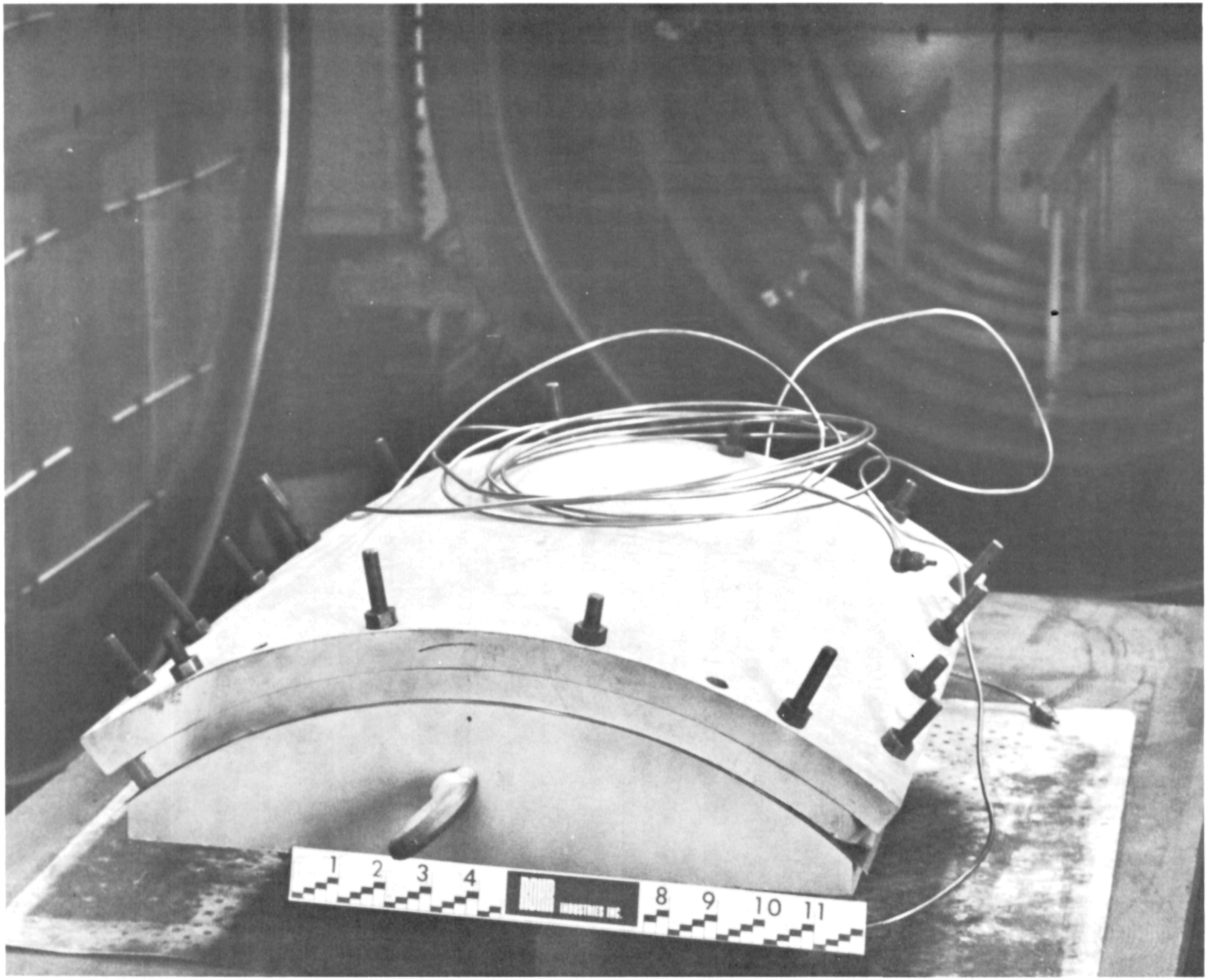

Figure 7. Tool for Superplastically Forming Skins Ready for Loading into Vacuum Furnace

LAYUP

The attachment clips and tongues were hot formed, machined, plated and resistance tack-welded to the inner skin prior to layup. The tool used for superplastically forming the outer skin was used as a layup jig for prepositioning the skins, dimpled sheets, and septum sheets, as shown in Figure 8. These prepositioned parts were held in position prior to diffusion bonding by resistance tack-welding through the nodes near each of the four corners.

LIQUID INTERFACE DIFFUSION BONDING

For LID bonding, the assembled detail parts were removed from the forming tool and placed on a radially shaped graphite reference block with 18 mm (0.7 inch) thick blocks placed on each of the 4 sides, shown in Figure 9. These blocks were fabricated to fit the preformed stepped edge closures of the skins and were used to apply bonding pressure to the region of the edge closures during the LID bonding cycle. The side blocks also controlled the panel height and prevented the panel from being crushed by the graphite block that was placed on top of the layup to apply bonding pressure to the main surface of the panel. The assembly, shown in Figure 10, was then placed into a vacuum furnace for LID bonding. The furnace was evacuated to 1×10^{-5} torr, heated to 1214 K (1725°F), and held for a specified period of time. During this period the plated material formed a eutectic melt and certain constituents of the eutectic diffused into the Ti-6Al-4V. This diffusion changed the composition of the eutectic and it resolidified, creating a bond joint at all plated interfaces. The tool was furnace cooled to 425 K (300°F) before being removed from the furnace. Examination of the part, shown in Figures 11 and 12, revealed that the LID bonded panel met the dimensional requirements.

Figure 8. Skins, Dimpled Sheets and Septum Sheets Being Laid up for LID Bonding

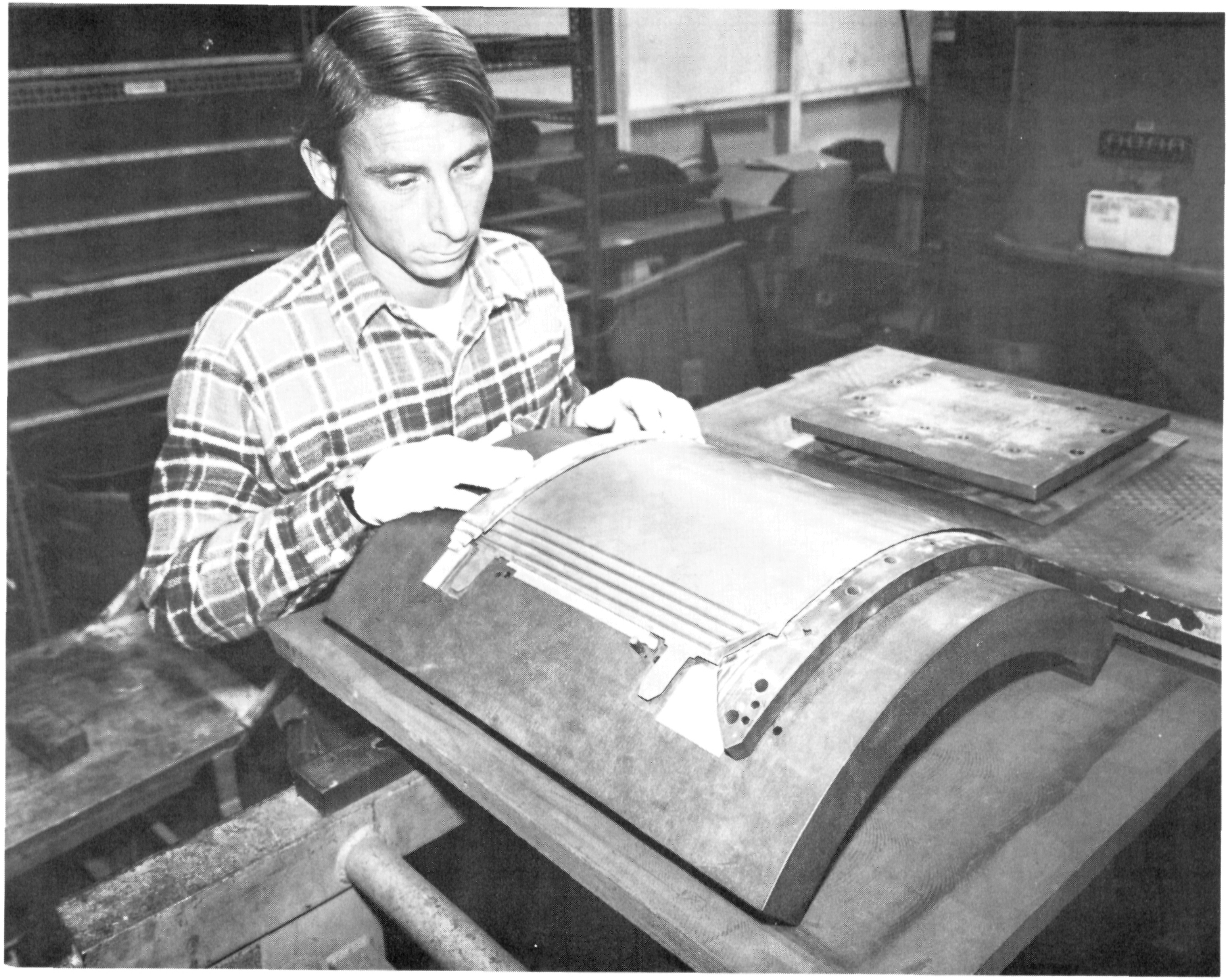

Figure 9. Assembly Being Placed on Graphite Block for LID Bonding

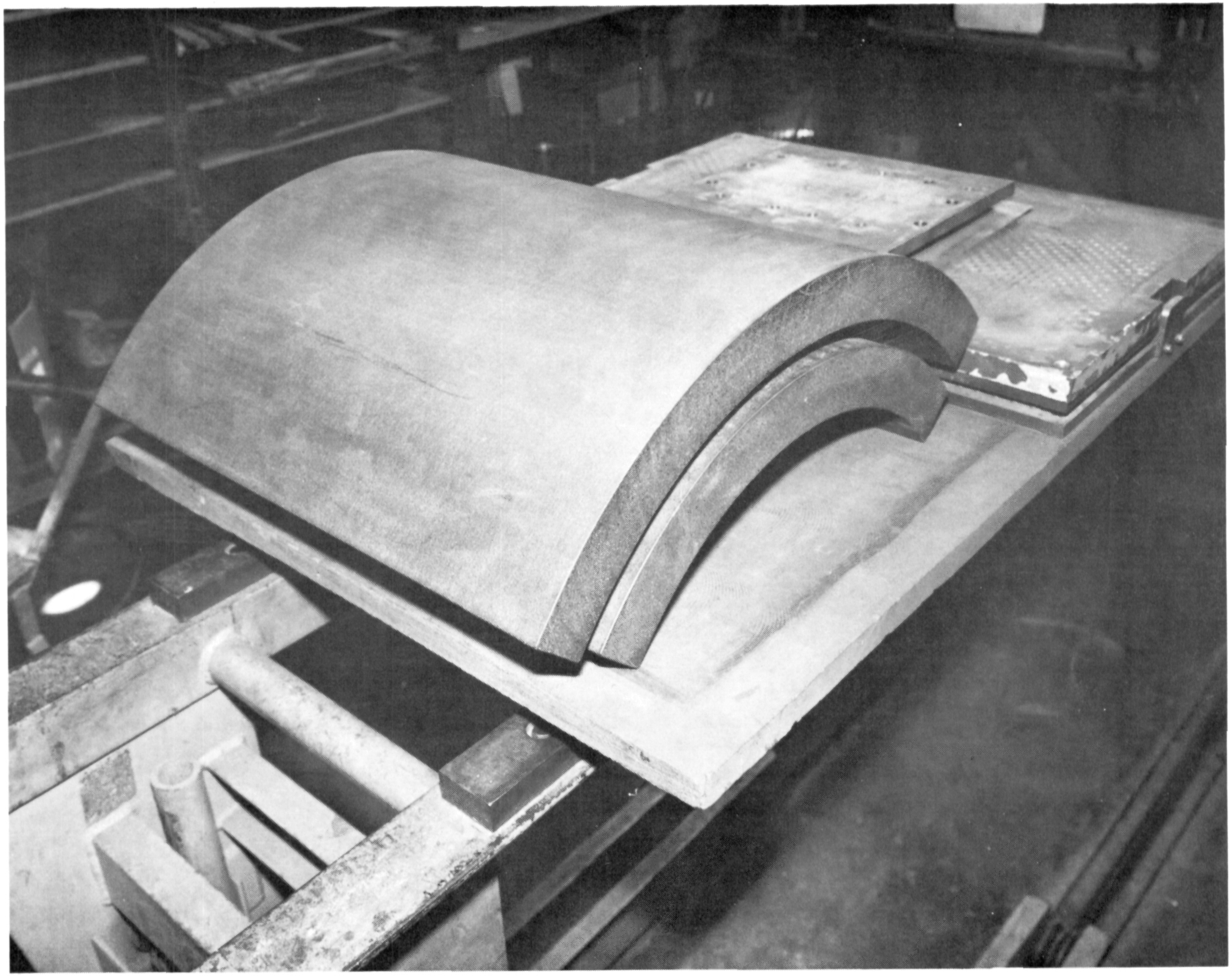

Figure 10. The Assembly Ready for Placing into Vacuum Furnace for LID Bonding

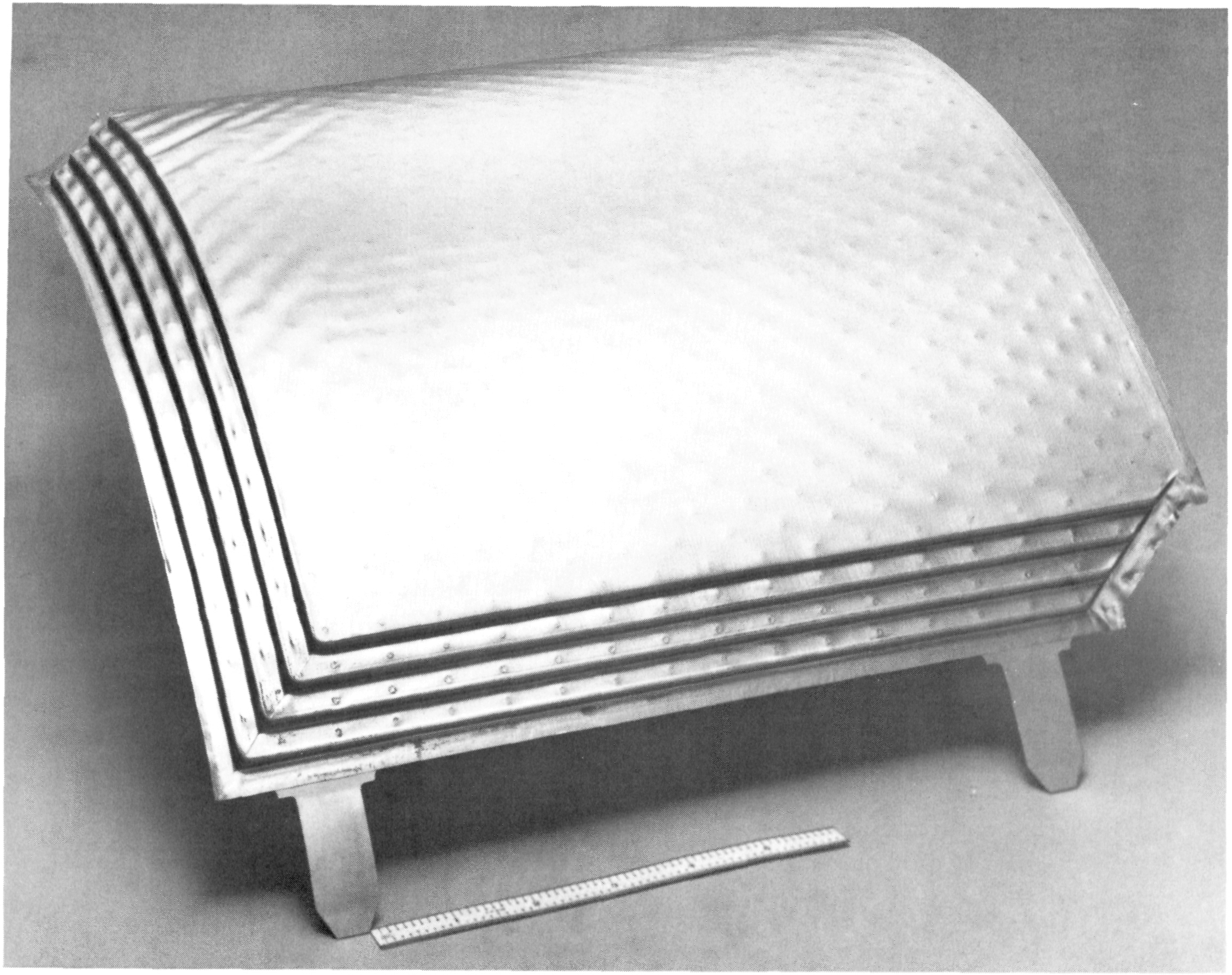

Figure 11. LID Bonded Panel, Outer Surface

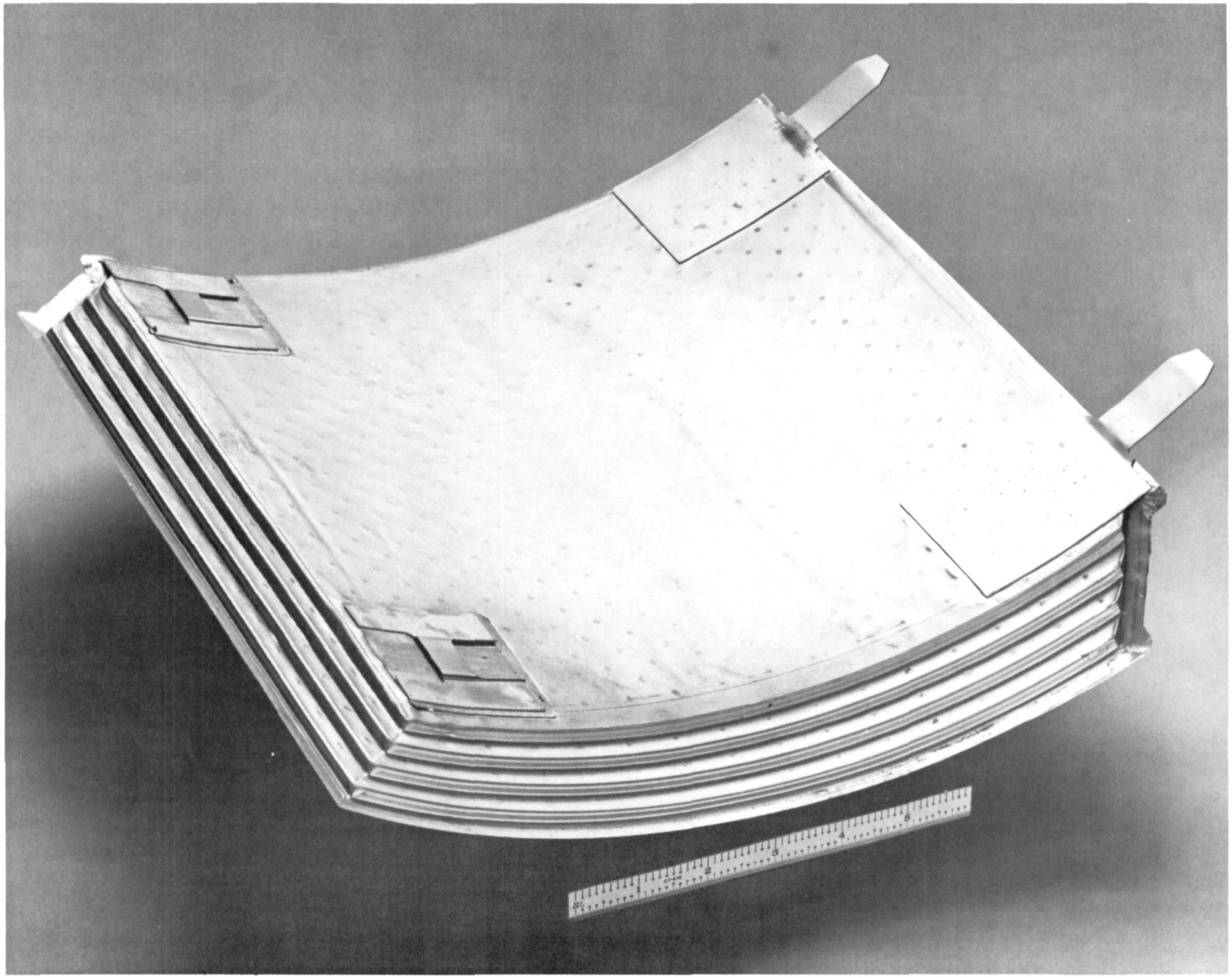

Figure 12. LID Bonded Panel, Inner Surface

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CONCLUSION

The fabrication of a curved multiwall panel has been demonstrated by superplastically forming the varius components and LID bonding the assembly of these components to achieve a panel with a single radius of curvature of 30.48 cm (12 inch).

The design changes employed in producing this panel were effective. The panel had good bond quality including the nodes along the stepped sides which could not be properly LID bonded using the previous design.

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REFERENCES

1. Blair, Winford; Meaney, John E. Jr.; and Rosenthal, Herman A; Design and Fabrication of Titanium Multi-Wall Thermal Protection System (TPS) Test Panels, NASA CR-159241, February, 1980.

2. Blair, W.; Meaney, J.E., Jr.; and Rosenthal, H.A.; Fabrication of Titanium Multi-Wall Thermal Protection System (TPS) Test Panel Arrays, NASA CR-159383, December, 1980.

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15. Supplementary Notes

Langley technical monitor:John Shideler
Interim Report

16. Abstract

A method was developed for fabricating curved titanium multiwall panels having a single radius of curvature of 30.5 cm (12 inches). A panel 30.5 x 30.5 x 1.7 cm (12 x 12 x .688 inch) having 4 dimpled sheets, 5 undimpled sheets, and stepped side closures was designed, fabricated and delivered to NASA Langley Research Center for evaluation.

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